HEINRICH RUDOLF HERTZ

(A paper on the life and work of Heinrich Rudolf Hertz read to the Wireless Institute of Australia, New South Wales Division, V.h.f. Group)

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INTRODUCTION

There are those who, like Henry Ford, consider history to be "the bunk"—but contemporary history caught up with Ford, as it eventually does with all who disregard that which has gone before. We can be sure that those who are presently "great" as the result of publicity will be allotted their appropriate place in the future and that those, whose significant contributions are not appreciated now, will be recognised as truly great at some later time—provided, of course, no Big Brother unwrites them from the history books.

The study of the lives of men who have made considerable contributions to our knowledge usually brings to light men of modesty and humility. They have found their personal reward in the search after truth, which they sought with zeal and devotion, without thought of self-aggrandisement. Hertz was such a man.

History, too, shows how great advances have been made by the observation and interpretation of apparently insignificant, even annoying, phenomena. Often these have been seen before by others, but the appreciation of their significance has awaited the notice of a man with a particular attitude of mind and background of training. As instance of this, we have recently seen the birth of a new concept in medical treatment—the introduction of penicillin and the other antibiotics—which had its origin in the chance contamination of a culture plate in Dr. Fleming's laboratory.

Except where it is shrouded by the veil of national security, or is a trade secret, scientific work is well reported—perhaps too well reported—in periodicals, books and communications to learned societies. It is on the record; and the careful experimenter makes sure that his claim to originality is a true one. In describing his work he points out what has already been done, and if his work is merely the confirmation or the development of the work of others, he states that it is so.

THE HEIDELBURG LECTURE

Hertz's contributions to physics covered many fields, but of particular interest to us are those dealing with the propagation of radio waves. I propose to commence this brief account of his work by reading a translation of part of his address given at the 62nd meeting of the German Association for the Advancement of Natural Science and Medicine at Heidelburg, on 20th September, 1889. Hertz was then 32 years old and he had completed his experimental and theoretical work on the propagation of electro-magnetic waves.

The lecture was entitled "On the relations between light and electricity." He described the work of Faraday and Clerk-Maxwell—the former spending his life seeking for proof of his concepts of lines of magnetic and electric force, the latter developing Faraday's ideas mathematically and proposing a phenomenon hitherto unknown — electric waves, which would be transversal waves, of any wavelength, but which would always be propagated in the ether with the same velocity—that of light. Hertz continued by stating that it was at this point—some 20 years after the publication of Clerk-Maxwell's work—that he was so fortunate as to be able to take part in the work. The translation by Jones and Schott (with minor amendments) then reads as follows:

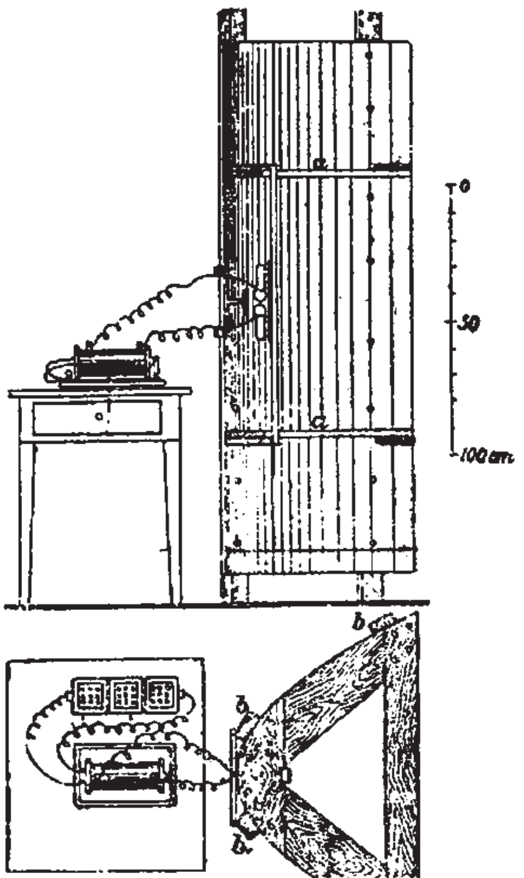

Fig. 1.

"Under suitable conditions the discharge of every kind of conductor gives rise to oscillations. These oscillations may be much shorter than those obtained by the discharge of Leyden jars. When you discharge the conductor of an electrical machine you excite oscillations whose period lies between a hundred-millionth and a thousand-millionth of a second. These oscillations are few in number and rapidly die out.

"The action of these oscillations can be perceived at a distance of about ten meters by very simple means. Just at the spot where we wish to detect the force we place a conductor, say a straight wire, which is interrupted in the middle by a small spark-gap. The rapidly alternating force sets the electricity of the conductor in motion, and gives rise to a spark at the gap. The method had to be found by experience. For the sparks are microscopically short, scarcely a hundredth of a millimeter long; they only last about a millionth of a second; but in a perfectly dark room they are visible to an eye which has been well rested in the dark. Upon this thin thread hangs the success of our undertaking. In beginning it we are met by a number of questions. Under what conditions can we get the most powerful oscillations? These conditions we must carefully investigate and make the best use of. What is the best form we can give to the receiver? We may choose straight wires or circular wires, or conductors of other forms; in each case the choice will have some effect on the phenomena. When we have settled on the form, what size shall we select? We soon find that this is a matter of some importance, that a given conductor is not suitable for the investigation of all kinds of oscillations, that there are relations between the two which remind us of the phenomena of resonance in acoustics. And lastly, are there not an endless number of positions in which we can expose a given conductor to the oscillations? In some of these the sparks are strong; in others weaker, and in others they entirely disappear.

"If you give a physicist a number of tuning-forks and resonators and ask him to demonstrate to you the propagation in time of sound waves, he will find no difficulty in doing so, even within the narrow limits of a room. He places a tuning-fork anywhere in the room, listens with the resonator at various points around and observes the intensity of sound. He shows how at certain points this is very small, and how this arises from the fact that at these points every oscillation is annulled by another one which started subsequently but travelled to the point along a shorter path. When a shorter path requires less time than a longer one, the propagation is a propagation in time. Thus the problem is solved. But the physicist now further shows us that the positions of silence follow each other at regular and equal distances: from this he determines the wave length, and, if he knows the time of vibration of the fork, he can deduce the velocity of the wave.

"In exactly the same way we proceed with our electric waves. In place of the tuning fork we use an oscillating conductor. In place of the resonator we use our interrupted wire, which also may be called an electric resonator. We observe in certain places there are sparks at the gap, in others none; we see that the dead points follow each

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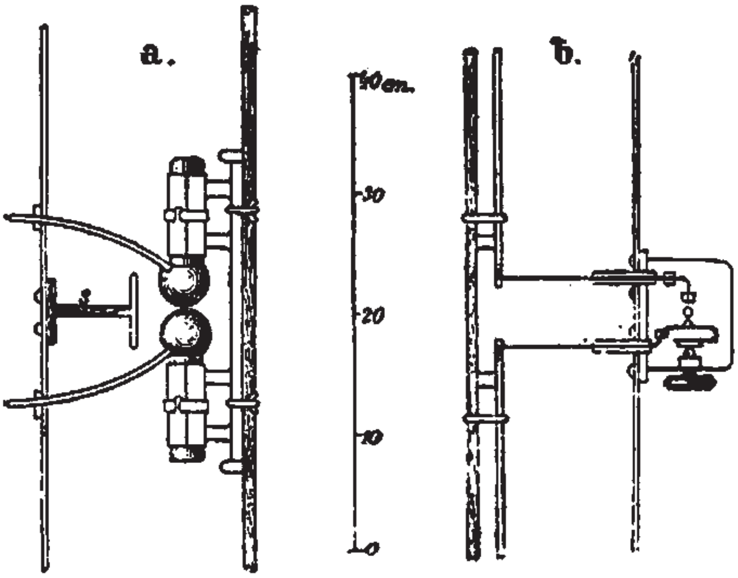

Fig. 2.

other in ordered succession. Thus the propagation in time is proved and the wave length can be measured. Next comes the question whether the waves thus demonstrated are longitudinal or transverse. At a given place we hold our wire in two different positions with reference to the wave: in one position it answers, in the other not. This is enough—the question is settled; our waves are transversal. Their velocity has now to be found. We multiply the measured wavelength by the calculated period of oscillation and find a velocity which is about that of light. If doubts are raised there is still another method open to us. In wires, as well as in air, the velocity of electric waves is enormously great, so that we can make direct comparison between the two. Now the velocity of electric waves in wires has long since been directly measured. This was an easier problem to solve, because such waves can be followed for several kilometers. Thus we obtain another measurement, purely experimental, of our velocity, and if the result is only an approximate one it at any rate does not contradict the first.

"With the aid of our electric waves we can directly exhibit the phenomena of light. We set up the conductor in which the oscillations are excited in the focal line of a very large concave mirror. The waves are thus kept together and proceed from the mirror as a powerful parallel beam. We cannot indeed see this beam directly, or feel it; its effects are manifest in exciting sparks in the conductors upon which it impinges. It only becomes visible to our eyes when they are armed with our resonators. But in other respects it is really a beam of light. By rotating the mirror we can send it in various directions, and by examining the path which it follows we can prove that it travels in a straight line. If we place a conducting body in its path we find that the beam does not pass through—it throws shadows. In doing this we do not extinguish the beam, but only throw it back: we can follow the reflected beam and convince ourselves that the laws of its reflection are the same as those of the reflection of light. We can also refract the beam in the same way as light. In order to refract a beam of light we send it through a prism, and it then suffers a deviation from its straight path. In the present case we proceed in the same way and obtain the same result; excepting that the dimensions of the waves and of the beam make it necessary for us to use a very large prism. For this reason we make our prism of a cheap material, such as pitch as asphalt. Lastly, we can with our beam observe those phenomena which hitherto have never been observed excepting with beams of light — the phenomena of polarisation. By interposing a suitable wire grating in the path of the beam we can extinguish or excite the sparks in our resonator in accordance with just the same laws as those which govern the brightening or darkening of the field of view in a polarising apparatus when we interpose a crystalline plate."

SOME OF HERTZ'S EQUIPMENT

As Hertz's experiments on radio waves were conducted in the room of a university building, they were, of necessity, conducted in that part of the spectrum now classified as the very high frequencies. V.h.f. was necessary so that observations could be made over several wavelengths and yet be within the range of the method of detection.

Figures 1 and 2 illustrate the construction of his oscillator and receiver in the experiments using the parabolic beam antenna. In these experiments he was operating on about 66 centimeters (or about 450 megacycles).

In demonstrating stationary electrical vibrations he used a different oscillator which operated on about eight meters. This is shown in Figure 3.

He derived the figure of 280,000 kilometers per second as the velocity of propagation using waves 2.8 meters in length and vibrating one hundred million times per second.

HERTZ'S POSITION IN THE HISTORY OF THE DEVELOPMENT OF RADIO

For the information of the V.h.f. Group it should be pointed out that Hertz was not the first man to operate on two meters. This honour, if such it be, is due to Professor G. F. Fitzgerald, who opened up this band in Dublin, in 1883—just 72 years ago. Hertz was unaware of this work and had to find the v.h.f. bands for himself.

The work of Faraday and Clerk-Maxwell has already been mentioned. Joseph Henry and Oliver Lodge had come near to demonstrating electromagnetic waves and von Bezold had written of electrical surgings or waves in short wires and of the interference between ordinary and reflected waves.

But to Hertz is given the credit of the first unequivocal experimental demonstration of the propagation of what he called electric waves and his work fulfilled all the postulates of Clerk-Maxwell. The story is a fascinating one —the prediction of a phenomenon not appreciable by man's unaided senses—this prediction arising as the result of Clerk-Maxwell's mathematical treatment of Faraday's conceptions of lines of force. Similarly, we have more recently seen the theoretical considerations of the atom practically demonstrated in a much more violent form.

The publication of Hertz's work was, of course, followed by some controversy —he had made an error in calculating his frequency of oscillation, and so on— but his results were confirmed and with his work began an epoch in the history of experimental physics. More sensitive methods of detecting electric waves were soon discovered, but Hertz did not live long to see the vast development of his researches.

Before we turn to the story of his life, some mention should be made of his work in other branches of physics for he published 18 other papers besides those which were collected in his book on electric waves.

SOME OF HERTZ'S OTHER CONTRIBUTIONS TO PHYSICS

These included a treatise on the Principles of Mechanics, work on induction, elasticity and hardness, evaporation of liquids including the description of a new hygrometer, invention of a hot-

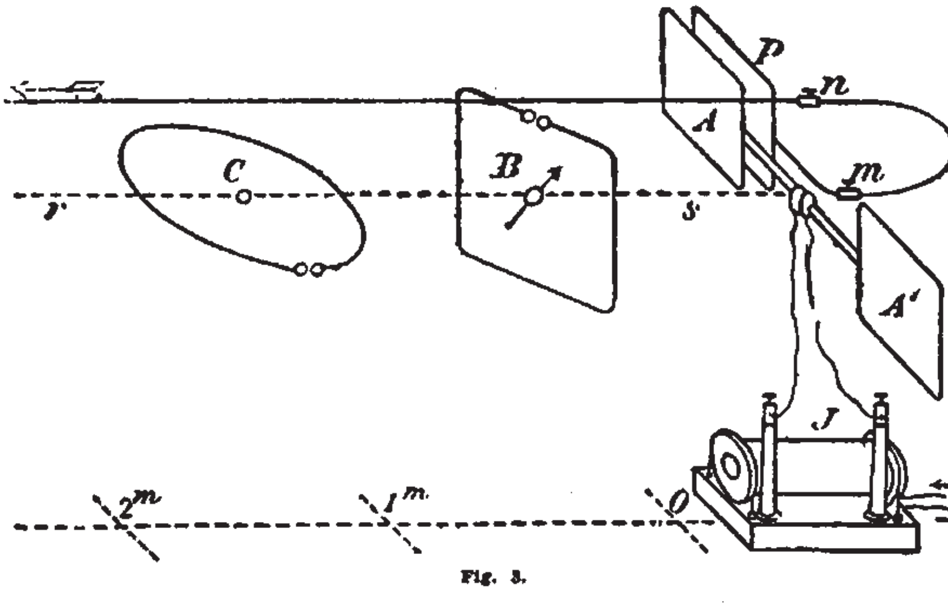

Fig. 3.

wire ammeter, and just before his death he discovered that cathode rays would pass through thin metallic layers, thus foreshadowing the development of X-rays.

All of this was compressed into a life span of just under 37 years.

CURRICULUM VITAE

Heinrich Rudolf Hertz was born 22nd February, 1857, in Hamburg. Partly of Jewish origin, he was the son of Dr. Gustav Hertz, a barrister who later became senator. As a boy he attended the municipal primary school and, after a year's preparation at home, proceeded to the Hamburg High School; here he matriculated in 1875, at the age of 18 years. Even while he was attending school his interests had become manifest—he worked at home at his bench and lathe and attended the Trade School on Sundays to practise geometrical drawing.

In 1877 he went to the University of Munich to continue his training in engineering, for which he had already prepared himself by the study of mathematics and natural science. However, after careful consideration, he decided that he would not be satisfied with engineering although it was a profession in which he would be certain to earn his livelihood. He wrote and asked his father if he would support him through the studies of the natural sciences in which persuit he obtained much more satisfaction. Having obtained permission to change his course, he spent a year at Munich attending courses in mathematics, mechanics and practical physics.

In 1878 he went to Berlin University and found that there was a prize being offered for the solution of a problem in physics dealing with electrical inertia. He discussed this with von Helmholtz and decided to attempt to solve it. He was given a room to work in and received the interested attention of von Helmholtz. He attended lectures in the morning and worked on his problem in the afternoon, reading the literature at night. He solved the problem and then wrote up his results while doing his military service at Freiburg. His research gained him the prize of a gold medal.

He then turned his attention to induction, and also attended lectures by Kirchhoff on magnetism. He wrote to his parents that much of what he was told he had already worked out for himself. His work on induction formed the thesis for his doctorate which he secured in 1880.

For the next three years he worked as demonstrator in the physics laboratory as assistant to von Helmholtz. Some of his work at this time dealt with cathode rays and he was so anxious to get on with it that he could not wait the two days for tubes to be made on order by the glass-blower: he made them himself. In 1883 he moved to Kiel with promotion to Privat Docent, or unpaid lecturer. Two years later he was called to Karlsruhe where he became ordinary Professor of Physics and where he was able to carry out his work on electric waves. Here, too, he married Miss Elizabeth Doll, the daughter of one of his colleagues.

In 1889 he attended the meeting of the German Association for the Advancement of Natural Science and read his paper on light and electricity. In the same year he became Professor of Physics at the University of Bonn. In these, his last years, he received honours from many learned societies in many countries, including the Rumford Medal of the Royal Society. In 1892 he became ill, but an operation was performed at the end of the year which allowed him to continue lecturing, with great effort, until 7th December, 1893. He died on New Year's Day, 1894.

Of his early death von Helmholtz said that " in old classical times it would have been said that he had fallen a victim to the envy of the gods." He added that Hertz's memory would live not only through his work, but also through his modesty, his warm recognition of the labours of others, and his genuine gratitude towards his teachers. Although naturally quiet, Hertz could be convivial with friends, and enliven discourse by many an apt remark. He never made an enemy, although he knew how to judge slovenly work, and to appraise at its true value any pretentious claim to scientific recognition.

Dr. Oliver Lodge spoke of Hertz's death as weakening the front ranks of scientific workers—the untimely end of a young and brilliant career which, however, had effected an achievement which would hand his name down to posterity. "Never was there a man more painfully anxious to avoid wounding the susceptibility of others."

REFERENCES

For those of you who wish to share the enjoyment of Hertz in his work, his papers have been collected in three volumes in English, translated by D. E. Jones and G. H. Schott, published by MacMillan & Company, as: "Electric Waves," in 1893, with a preface by Lord Kelvin; "Miscellaneous Papers," in 1896, with an introduction by Professor Lenard; and "The Principles of Mechanics," in 1899, with an introduction by von Helmholtz. In an introduction to "Electric Waves," Hertz goes through the period of his experimental work, recording his hopes, ideas, difficulties and interpretations so that we have here a record of his mind at work—a rare thing in the history of scientific discovery.

In addition, there is "Signalling through space without wires: the work of Hertz and his successors," by Oliver J. Lodge, published (undated) in "The Electrician" Series, London. Hertz's experiments were also described in outline by Sir Joseph J. Thomson in an article in the Encyclopoedia Britannica.

HINTS AND KINKS

FINISHING TEST INSTRUMENT PANELS

A very fine and workman-like finish can be made with panels for test instruments, etc., by first cleaning the aluminium panel with some steel wool and spraying (a fly spray is excellent for the job) with clear varnish as used for coating charcoal and pencil sketches. This varnish can be obtained from most stores dealing in artists' colours and oils.

Another good clear coating (which the writer prefers) is ordinary clear nail lacquer. This can be brushed on with a fine camel hair brush or even the small brush that comes with the bottle. It leaves a very clear and durable finish.

If prior to varnishing, the panel is drilled and lettering done with black Indian ink, a quite professional job results and the coat of lacquer protects the ink from cracking or being rubbed off.—VK3SZ (reprinted from "A.R.," Jan. 1946).